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[Scope of Claims]

[Claim 1] A photonic switching method of switching input electrical signals input from a plurality of input parts to a plurality of output parts by utilizing optical signals that have been respectively converted from the input electrical signals, the photonic switching method being characterized by comprising the steps of:

converting a plurality of input electrical signals into optical signals in such a manner that the optical signals maintain the same pulse interval therein as that of the electrical signals;

multiplexing the converted optical signals in such a manner that the optical signals do not overlap on a time axis by adjusting a timing within the pulse interval;

distributing the multiplexed optical signals to a plurality of output parts; and

separating, in each of the output parts, one optical signal to be output from the output part, from among the distributed multiplexed optical signals by employing a mutual optical interaction.

[Claim 2] A photonic switch for switching input electrical signals input from a plurality of input parts to a plurality of output parts by utilizing optical signals that have been respectively converted from the input electrical signals, the photonic switch being characterized by comprising:

an optical multiplexing unit for:

converting a plurality of input electrical signals into optical signals in such a manner that the optical signals maintain the same pulse interval of the electrical signals;

adjusting a timing of the converted optical signals within the time of pulse interval; and

multiplexing the timing adjusted optical signals such that the optical signals do not overlap on a time axis with one another;

a signal distribution unit for distributing the multiplexed optical signals generated by the optical multiplexing unit to respective output parts; and

optical multiplexing separation units, each serving as the output part, for separating an optical signal to be output from the output part, from among the distributed multiplexed optical signals by employing a mutual optical interaction.

[Detailed Description of the Invention]

[0001]

[Field of the Industrial Application] The present invention relates to a photonic switching method and a photonic switch utilizing the method.

[0002]

[Prior Art] A conventional photonic switch, with input electrical signals input from a plurality of input parts being switched to

a plurality of output parts, in which the switching operation is performed by utilizing optical signals converted from the input electrical signals, has been disclosed in, for example, "System experiments of a 25 Gbit/sULPHA Switch", Technical Report of The Institute of Electronics Information and Communication Engineers, SSE92-69(October, 1992) of Document 1. In the above photonic switching method, data portions of packet-state electrical signals with a bit rate V respectively input from each input part are converted by employing a stream of ultra-short optical pulses into ultra-fast optical cells with a bit rate nV . Address portions of the packet-state electrical signals are also converted into optical address signals having a different wavelength from that employed to produce the optical cells. The ultra-fast optical cells and address signals produced in similar manners at each of the input parts are respectively time-division multiplexed by a star coupler to obtain multiplexed optical signals. These multiplexed optical signals are respectively transferred to a plurality of output parts each constituted of a cell selector, a cell buffer, and a cell decoder. Each cell selector incorporates therein a laser diode (LD) gate switch. A desired ultra-fast optical cell can be derived from the multiplexed optical signals by driving the LD gate switch in accordance with the address signal converted into the electrical signal. The derived ultra-fast optical cell is controlled in contention by the cell buffer and converted again into the electrical signal with the bit rate V by

the cell decoder.

[0003]

[Problems to be solved by the Invention] However, the conventional technology has allowed the packet-state electrical signals with the bit rate V input respectively from the input parts to be converted into the ultra-fast optical cells simply in a manner to be compressed on the time axis, and time-division multiplexed. Therefore, buffering after the cells have been selected at the output parts should be performed with an ultra-fast bit rate nV . Furthermore, it requires that the ultra-fast optical signal should be converted into a low speed optical signal so as to be easily processed by successive electrical circuits and that the low speed optical signal should be further processed to be converted into an electrical signal packet.

[0004] Also, a desired cell has been selected among the multiplexed optical signals by employing the LD gate switch. The LD gate switch is, however, operable only in a range of a few tens to a few hundreds GHz and inoperable at a speed of THz, thereby causing difficulty in achieving large capacities.

[0005]

[Means for solving the Problems] According to a primary invention of the present application, to accomplish the above objects, there is provided a photonic switching method of switching input electrical signals input from a plurality of input parts to a plurality of

output parts by utilizing optical signals that have been respectively converted from the input electrical signals, the photonic switching method being characterized by including the steps of: converting the respective input electrical signals into optical signals in such a manner that the optical signals maintain the same pulse interval therein as that of the electrical signals; multiplexing the converted optical signals in such a manner that each of the optical signals does not overlap on a time axis with each other by adjusting the timing of the converted optical signals within the time of the pulse interval; distributing the multiplexed optical signals to respective output parts; and separating, in each of the output parts, the optical signal to be output from the output part from among the distributed multiplexed optical signals by employing a mutual optical interaction.

[0006] According to a secondary invention of the present application, there is provided a photonic switch for switching input electrical signals input from a plurality of input parts to a plurality of output parts by utilizing optical signals that have been respectively converted from the input electrical signals, the photonic switch characterized by including: an optical multiplexing unit for converting the respective input electrical signals into optical signals in such a manner that the optical signals maintain the same pulse interval of the electrical signals, adjusting the timing of the converted optical signals within the time of the pulse intervals,

and multiplexing the timing adjusted optical signals such that each of the optical signals is not overlapped on a time axis with each other; a signal distribution unit for distributing the multiplexed optical signals generated by the optical multiplexing unit to respective output parts; and an optical multiplexing separation unit, each serving as the output part, for separating an optical signal to be output from the output parts from among the distributed multiplexed optical signals by employing a mutual optical interaction.

[0007]

[Operation] According to configurations of primary and secondary inventions, each of the optical signals obtained by electro-optical conversion of the input electrical signal input through each of the input parts maintains the same pulse interval of the input electrical signals. Further, multiplexed optical signals are generated in a bit-interleave manner so that the optical signal pulses related to one specific input part are interleaved one by one between each of the pulses that are adjacent to the optical signals related to the input parts. In other words, multiplexed optical signals, each of which relates to different input parts, are adjacently interleaved with each other while maintaining the same pulse interval of the input electrical signal, are generated.

[0008] The multiplexed optical signals are respectively transferred to the output parts. The optical signals, each of which relates

to the respective input parts, can be transferred to the output parts substantially at the same time with the pulse interval of the input electrical signals being maintained, so that a large amount of optical signals can be transferred to the output parts as in the conventional invention, with the pulse interval of the input electrical signals being maintained.

[0009] On the other hand, each of the output parts separates the optical signal from among the multiplexed optical signals by utilizing a mutual optical interaction, which can accomplish separation at a higher speed than separation utilizing the electrical signal.

[0010]

[Embodiments] Hereinafter, a description will be presented of embodiments of primary and secondary inventions with reference to the attached drawings, whereas all of the drawings illustrate an arrangement of the respective configuration components schematically insofar as to be apprehended. It is to be noted that like reference characters denote like parts of similar configuration components in each drawing.

[0011] 1. First Embodiment

FIG. 1 is a block diagram illustrating an entire configuration of a photonic switch according to a first and second embodiment of the present invention, and FIG. 2 is a detailed structural diagram of the photonic switch according to the first embodiment. In FIG. 1, numerals 11, 13, 15, and 17 respectively denote a header reading

unit, an output control unit, an optical multiplexing unit, and a signal distributing unit. Reference numerals 19a to 19d, 21a to 21d, and Ea to Ed also respectively denote optical multiplexing separation units as respective output parts, input terminals as respective input parts, and input electrical signals respectively input to the input parts 21a to 21d. In this embodiment, each of the input electrical signals Ea to Ed is a packet-state electrical signal constituted of a header portion and a data portion, and controlled by a same single clock signal.

[0012] The header reading unit 11, which can be conventionally constituted, reads information, that is, path information included in the header portion of the packet-state input electrical signal, and transmits the path information to the output control unit 13 in a successive stage.

[0013] The output control unit 13 generates a control signal for controlling an output destination for the data portion of the input electrical signal corresponding to the header portion with reference to the path information transmitted from the header reading unit 11, and transmits the control signal to the optical multiplexing separation unit 19a to 19d.

[0014] The optical multiplexing unit 15 converts each of the input electric signals Ea to Ed input from the input parts 21a to 21d into optical signals while maintaining the pulse interval of the input electric signals, and adjusts the timings of the converted

optical signals within the time of the pulse interval so that the optical signals are multiplexed without being overlapped with each other on a time axis. The optical multiplexing unit 15 according to the first embodiment is constituted as described hereinafter with reference to FIG. 2. In other words, the optical multiplexing unit 15 according to the first embodiment is constituted of modulators 15aa to 15ad each being connected to a corresponding one of the input parts 21a to 21d, a single pulse (optical pulse) generator 15b connected respectively to the modulators 15aa to 15ad, optical delay lines 15ca to 15cd which are connected to the rear stages of the corresponding modulators 15aa to 15ad and capable of setting predetermined periods of delay time, and a multiplexer 15d for multiplexing the optical outputs emitted from the optical delay lines 15ca to 15cd.

[0015] The optical multiplexing unit 15 operates such that each of the modulators 15aa to 15ad opens respective gates upon reception of the input electrical signal so as to output the light transmitted from the pulse generator 15b to the successive stage. Accordingly, each of the modulators 15aa to 15ad converts one bit of the input electric signal into one bit of the optical pulse so that electro-optical conversion is performed while maintaining the pulse interval of the input electrical signal.

[0016] The optical delay lines 15ca to 15cd of the optical multiplexing unit 15 adjust the timings of the optical signals generated by the

modulators 15aa to 15ad within the time of the pulse interval (referred to as "S" in FIG. 3) so that the optical signals do not overlap with each other on the time axis. In this embodiment, the optical delay lines 15ca to 15cd are constituted of waveguides such as optical fibers which are adjusted in length so as to generate a predetermined delay time between each of the optical signals. Timing lines La to Ld in FIG. 3 shows one example of the timings of the optical signals La to Ld which are passed through the optical delay lines 15ca to 15cd. As can be seen from the timing lines, the optical signals La to Ld maintain an original pulse interval S. Moreover, as a result of timing adjustment, performed by the optical delay lines 15ca to 15cd, the optical signals La to Ld are shifted in timing with each other within a range of the pulse interval S in a manner so as not to be overlapped with one another on the time axis. In FIG. 3, a region shown as X is a region where packet information is output, and a region shown as Y is a region for guard time. The same definition will be made in FIGS. 5 and 8.

[0017] The multiplexer 15d of the optical multiplexing unit 15 multiplexes the timing-adjusted optical signals La to Ld adjusted by the optical delay lines 15ca to 15cd. A timing line L in FIG. 3 shows multiplexed optical signals L obtained by multiplexing the optical signals La to Ld with the multiplexer 15d. The time axis of the timing line L in FIG. 3 is, however, expanded as compared with that of the timing lines of the optical signals La to Ld in

FIG. 3 in order to avoid complication of the drawings. As is obvious from the timing line L in FIG. 3, the multiplexed optical signals produced in accordance with the present invention are obtained by multiplexing the optical signal in connection with a certain input part in a bit-interleave manner between adjacent pulses of another optical signal which is multiplexed in connection with another input part while electro-optically converting the input electric signals to maintain the pulse interval. For example, in the timing line L of FIG. 3, each pulse of b, c, and d is interleaved between adjacent pulses a and a having the pulse interval S. In other words, according to this embodiment, the multiplexed optical signals L are obtained by multiplexing in such a manner that the optical signals corresponding to the number of input parts are multiplexed in a bit-interleaving manner like abcdabcd..., while maintaining the pulse interval of the input electric signals Ea to Ed.

[0018] Next, a description of the signal distributing unit 17 will be presented. The signal distributing unit 17 distributes the multiplexed optical signals L generated by the optical multiplexing unit 15 into the successive multiplexed signal separation units 19a to 19d. The signal distributing unit 17 of this embodiment is constituted of a star coupler.

[0019] A description of a configuration and operation of the multiplexed signal separation units 19a to 19d will now be presented.

[0020] The multiplexed signal separation units 19a to 19d are utilized

for separating the optical signal to be output from the predetermined output part, from among the multiplexed optical signals by employing a mutual optical interaction. In this embodiment, optical four wave mixing phenomenon is employed as the mutual optical interaction. Therefore, each of the multiplexed signal separation units 19a to 19d according to the present embodiment is constituted, as shown in FIG. 4, of an optical four wave mixer 191 for distributed light from the signal distributing unit (star coupler) 17 to be input, an optical pulse source 193 connected to the optical four wave mixer 191, a filter 195 disposed at the rear stage of the optical four wave mixer 191, and an opto-electrical converter 197 disposed at the rear stage of the filter 195. However, the opto-electrical converter 197 is not necessarily included in the concept of the multiplexed signal separation unit, but can be included in the successive circuit configuration components or an independent component.

[0021] The optical four wave mixer 191 can be generally made of a non-linear medium. The optical pulse source 193 starts to output the input electrical signals E_a to E_d , and a pulse train having the same pulse interval (hereinafter referred to as pumping light) as the pulse interval S in the optical signal obtained by the electro-optical conversion in accordance with the control signal from the output control unit (see FIG. 1). The filter 195 is constituted of a conventional wavelength filter and the opto-electrical converter

197 is constituted of a conventional material, for example, a photo receiving element.

[0022] In the multiplexed signal separation units 19a to 19d shown in FIG. 4, the multiplexed optical signals L (see FIG. 3) from the star coupler 17 and the pumping light from the optical pulse source 193 are concurrently input to the optical four wave mixer 191. Since only an optical signal, among the multiplexed optical signals L, coinciding with the pumping light in timing exceeds a threshold value of the optical four wave mixer 191, only such the optical signal is converted in wavelength. The wavelength converted light is output to the filter 195 side together with the pumping light from the optical pulse source and the multiplexed signals, while the filter 195 selectively transmits the wavelength converted light.

[0023] Now, a detailed description will be presented as to the operations of the optical four wave mixer 191 and the filter 195 with reference to FIGS. 5(A) to 5(C). FIG. 5(A) shows the multiplexed optical signals L, FIG. 5(B) shows the pumping light output through the optical pulse source 193 shown in FIG. 4, and FIG. 5(C) shows the output light output through the filter 195 of a certain output part.

[0024] The pumping light output through the optical pulse source 193 has the same pulse interval as the pulse interval S of an input electric signal or the optical signal obtained by electro-optical conversion as shown above in FIG. 5(B). Moreover, the pumping light

can be controlled in output timing by the control signal from the output control unit 13 (see FIG. 1) while maintaining the pulse interval S . For example, FIG. 5(B) shows that the pumping light is output with a delay time t relative to the output of the multiplexed optical signals L in the front portion, that is, the portion in front of the guard time region Y , and that the pumping light coincides in timing with the optical signal shown as b . In this case, since the optical four wave mixture function is caused upon the optical signal b , the signal b is output through the filter 195. The latter portions shown in FIG. 5(B) illustrates that the pumping light coincides in timing with the optical signal shown as a . In this case, the four optical wave mixture function is caused upon the optical signal a so that the signal a is output through the filter 195. An output timing adjustment for the pumping light can be performed by utilizing, for example, the guard time Y .

[0025] As can be understood from the above description of the first embodiment, since the signal output through the filter 195 maintains the pulse interval S of the input electrical signal, it has a pulse stream with a speed which can be electrically handled. Accordingly, the opto-electrical conversion can be facilitated, and buffering and jitter processing after the opto-electrical conversion can be also easily performed.

[0026] 2. Second Embodiment

Next, a description of a second embodiment will be presented

with reference to FIGS. 6 to 8. The above-described first embodiment is constructed such that the optical signal that should be output at the predetermined output part is selected from among the multiplexed optical signals by adjusting the timing with which the pumping light is input to the optical multiplexing separation unit. However, a so-called address processing that selects a desired optical signal from among the multiplexed optical signals can be performed at the optical multiplexing unit side, which is realized in the second embodiment.

[0027] The configurations of the optical multiplexing unit and the optical multiplexing separation units of the second embodiment are structured as shown respectively in FIGS. 6 and 7.

[0028] An optical multiplexing unit 15x of the second embodiment (see FIG. 6) is structured similar to the first embodiment in that modulators 15aa to 15ad and a multiplexer 15d are incorporated thereinto. The optical multiplexing unit 15x further includes optical pulse sources 151a to 151d which are connected one by one to the corresponding modulators 15aa to 15ad and are variable in output timing. On the other hand, each of the optical multiplexing separation units 19xa to 19xd of the second embodiment, as in the first embodiment, has the optical four wave mixer 191, the filter 195, and the opto-electrical converter 197. A pulse train generator (optical source for pumping light) 199 is also provided thereto. However, the pulse train generator 199 in the second embodiment

is commonly used as a single optical source serving for the optical multiplexing separation units 19xa to 19xd. Further, the optical multiplexing separation units 19xa to 19xd in the second embodiment have optical delay lines 201a to 201c installed between the pulse train generator 199 and the optical four wave mixers 191 of the optical multiplexing separation units 19xa to 19xd so that the pumping light from the pulse train generator 199 is respectively input to each of the optical four wave mixers 191 in the optical multiplexing separation units 19xa to 19xd as optical pulse trains with different timings.

[0029] Next, a description will be presented of a photonic switch operation in the second embodiment with reference to FIGS. 6, 7, and 8(A) to 8(C). FIG. 8(A) shows an example of the multiplexed optical signals L output from the multiplexer 15d of the optical multiplexing unit 15x according to the second embodiment. FIG. 8(B) shows a pumping light input to the optical four wave mixer 191 in a certain optical multiplexing separation unit (hereinafter called a target optical multiplexing separation unit) among the optical multiplexing separation units 19xa to 19xd of the second embodiment. The pumping light is varied in timing depending on each of the optical multiplexing separation units 19xa to 19xd. FIG. 8(C) shows an output from the filter 195 at the target optical multiplexing separation unit.

[0030] According to the second embodiment, the header reading unit

11 reads addresses (path information) of the input electrical signals Ea to Ed, and the output control unit 13x adjusts the timings of the pulse trains of the timing variable optical pulse source 151a to 151d based on the path information. Then, the input electrical signals are, as in the first embodiment, respectively converted into optical signals with the pulse interval of the input electrical signals being maintained at each of the modulators 15aa to 15ad, so as not to overlap with one another on the time axis within the time of the pulse interval S. These optical signals are multiplexed at the multiplexer 15d. One example of the front portion (the portion before the boundary of the guard time Y) shown in FIG. 8(A) shows the multiplexed optical signals in which the timings of the optical pulse sources 151a to 151d are arranged in the order of 151c, 151a, 151b, and 151d. In this case, the pumping light and the optical signal c are concurrently input to the optical four wave mixer at the target optical multiplexing separation unit so that the optical signal c interacts with the optical four wave mixer, and thereby the optical signal c is output through the filter 195. Another example in the latter portion (the latter portion from the boundary of the guard time Y) shown in FIG. 8(B) shows a multiplexed optical signal in which the timings of the optical pulse sources 151a to 151d are arranged in the order of 151b, 151a, 151c, and 151d. In this case, the pumping light and the optical signal b are concurrently input to the optical four wave mixer at the target optical multiplexing

separation unit so that the optical signal b interacts with the four optical wave mixer, and thereby the optical signal b is output through the filter 195. As described above, the second embodiment is constructed such that the optical signal which exists within a predetermined time slot is assigned to a predetermined output part.

[0031] Although the foregoing description has been presented of specific embodiments according to the primary and secondary inventions, it is to be noted that these inventions are not limited to the above-mentioned embodiments. For example, each of the above-mentioned embodiments utilizes the mutual optical interaction phenomenon called the optical four wave mixture as the method for selecting the optical signal relevant to a certain input part among the multiplexed optical signals. However, the mutual optical interaction is not limited to the optical four wave mixture, but other adequate mutual optical interaction can also be employed. For example, a non-linear optical effect such as Kerr effect can be employed as a method for selecting the optical signal.

[0032] Further, although the above embodiments have four input and output parts, it should be clearly understood that the number is optional.

[0033]

[Effects of the Invention] As is obvious from the above description, a photonic switching method and a photonic switch according to the

present invention converts the input electric signals input through respective input parts into optical signals with the pulse interval of the input electric signals being maintained. Then, these converted optical signals are timing-adjusted within the time of the pulse interval, and multiplexed in such a manner that these optical signals do not overlap with one another on the time axis. The multiplexed optical signals are then transmitted to the output parts, and an optical signal to be output at the predetermined output part is separated from among the multiplexed optical signals by utilizing a mutual optical interaction. Accordingly, the opto-electrical conversion can be easily performed because the output optical signal is a signal having the pulse interval at the time of the input electrical signal, that is, the signal of the bit rate at the time of the input electrical signal. Further, the buffering processing can be facilitated after the opto-electrical conversion, and the jitter processing can be facilitated even when jitter exists.

[0034] Moreover, since the selection of a specific optical signal from among the multiplexed optical signals is performed by utilizing a mutual optical interaction, the operational speed can be remarkably enhanced as compared with the case in which such selection is made electrically.

[Brief Description of the Drawings]

[FIG. 1] A block diagram illustrating an entire configuration of a photonic switch according to first and second embodiments of the

present invention.

[FIG. 2] A structural diagram illustrating an optical multiplexing unit according to the first embodiment.

[FIG. 3] An explanatory view of the first embodiment.

[FIG. 4] A structural diagram illustrating a configuration of an optical multiplexing separation unit according to the first embodiment.

[FIG. 5] Explanatory diagrams explaining an operation of the optical multiplexing separation unit according to the first embodiment.

[FIG. 6] A structural diagram illustrating a configuration of an optical multiplexing unit according to a second embodiment.

[FIG. 7] A structural diagram illustrating a configuration of an optical multiplexing separation unit according to the second embodiment.

[FIG. 8] Explanatory diagrams illustrating an operation according to the second embodiment.

[Description of Symbols]

11: header reading unit

13: output control unit

15: optical multiplexing unit

17: signal distributing unit

19a-19d: optical multiplexed signal separation unit

Ea-Ed: input electric signal

S: pulse interval

15aa-15ad: modulator

15b: pulse generator

15ca-15cd: optical delay line

15d: multiplexer

191: optical four wave mixer

193: optical pulse source

195: filter

197: opto-electrical converter

13x: output control unit according to the second embodiment

15x: optical multiplexing unit according to the second embodiment

151a-151d: timing variable optical pulse source

19xa-19xd: optical multiplexing separation unit according to the second embodiment

199: pulse train generator

201a-201d: optical delay line

FIG. 1

11: HEADER READING UNIT

13: OUTPUT CONTROL UNIT

15: OPTICAL MULTIPLEXING UNIT

19a-19d: OPTICAL MULTIPLEXED SIGNAL SEPARATION UNIT

Ea-Ed: INPUT ELECTRIC SIGNAL

DIAGRAM USED FOR EXPLAINING FIRST AND SECOND EMBODIMENTS

FIG. 2

15aa-15ad: MODULATOR

15b: PULSE GENERATOR

15ca-15cd: OPTICAL DELAY LINE

15d: MULTIPLEXER

DIAGRAM ILLUSTRATING STRUCTURE OF OPTICAL MULTIPLEXING UNIT ACCORDING
TO FIRST EMBODIMENT

FIG. 3

La-Ld: OPTICAL SIGNAL

L: MULTIPLEXED OPTICAL SIGNAL

S: PULSE INTERVAL

X: PACKET

Y: GUARD TIME

DIAGRAM USED FOR EXPLAINING FIRST EMBODIMENT

FIG. 4

191: OPTICAL FOUR WAVE MIXER

193: OPTICAL PULSE SOURCE

195: FILTER

197: OPTO-ELECTRICAL CONVERTER

DIAGRAM ILLUSTRATING STRUCTURE OF OPTICAL MULTIPLEXING SEPARATION
UNIT ACCORDING TO FIRST EMBODIMENT

FIG. 5

(B) PUMPING LIGHT

(C) OUTPUT THROUGH FILTER

TIME

DIAGRAM USED FOR EXPLAINING OPERATION OF OPTICAL MULTIPLEXING
SEPARATION UNIT ACCORDING TO FIRST EMBODIMENT

FIG. 6

13x: OUTPUT CONTROL UNIT ACCORDING TO SECOND EMBODIMENT

15x: OPTICAL MULTIPLEXING UNIT ACCORDING TO SECOND EMBODIMENT

151a-151d: TIMING VARIABLE OPTICAL PULSE SOURCE

DIAGRAM ILLUSTRATING STRUCTURE OF OPTICAL MULTIPLEXING UNIT ACCORDING
TO SECOND EMBODIMENT

FIG. 7

19xa-19xd: OPTICAL MULTIPLEXING SEPARATION UNIT ACCORDING TO SECOND

EMBODIMENT

199: PULSE TRAIN GENERATOR

201a-201d: OPTICAL DELAY LINE

DIAGRAM ILLUSTRATING STRUCTURE OF OPTICAL MULTIPLEXING SEPARATION
UNIT ACCORDING TO SECOND EMBODIMENT

FIG. 8

(B) PUMPING LIGHT

(C) OUTPUT THROUGH FILTER 195

TIME

DIAGRAM USED FOR EXPLAINING OPERATION OF SECOND EMBODIMENT